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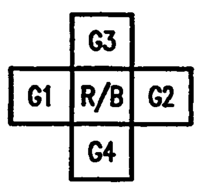


(57) Abstract

In a method of interpolating a color sample in a signal (RGBin) having alternately colored samples, the missing color sample is interpolated in dependence upon neighbouring color samples (G1, G2, G3, G4) of the same color (G) as the color sample to be interpolated, and a differently colored sample (R/B) from the same location as the color sample to be interpolated.

Color sample interpolation.

The invention relates to a method of and a device for interpolating a color sample in a signal having alternate colored samples, and to a camera comprising such a device.

It is, *inter alia,* an object of the invention to provide an interpolation aimed at furnishing a high color signal resolution. To this end, first and second aspects of the invention provide an interpolation method and an interpolation device as defined in claims 1 and 15, respectively. A third aspect of the invention provides a camera as defined in claim 16. Advantageous embodiments are defined in the dependent claims.

In a method of interpolating a color sample in a signal having alternate colored samples in accordance with a primary aspect of the present invention, the missing color sample is interpolated in dependence upon neighbouring color samples of the same color as the color sample to be interpolated, and a differently colored sample from the same location as the color sample to be interpolated.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

Figs. 1A and 1B show an RGB and a YeGCy Bayer filter, respectively;

Fig. 2 shows the sample structure of the RGB pixels and the pitch of the GRB colors obtained by an RGB Bayer filter;

Figs. 3A and 3B show a theoretical and a more realistic Nyquist domain of an RGB Bayer filter, respectively;

Fig. 4 shows a red or blue pixel at the position of a missing green pixel;

Figs. 5A and 5B show the near-white area for two different values of the parameters SmartGainR and SmartGainB;

Figs. 6A and 6B show two configurations of a white balance control

is repeated at multiples of the sample frequency of each color. The multiple sample frequencies are located at equal distances in a two-dimensional array.

Figs. 3A and 3B show the Nyquist domain corresponding to such an array with a very limited number of sample frequency points, because this number is theoretically infinite. In order to avoid aliasing, each spectrum around a sample frequency point should not overlap with the spectrum of its neighbor sample frequency points. If this is true, the Nyquist theorem is fulfilled, i.e. the incoming frequencies of the scene, supplied via the optical system and the integrating light-sensitive part of a pixel, should be lower than half the sample frequency of each color. Frequencies supplied outside this Nyquist domain will certainly cause aliasing. This means that the maximal resolution of each color is determined by half the sample frequency of each color. For Red and Blue, the maximum resolution in the horizontal and vertical directions is therefore $fsRB/2=fs/4$, and $\sqrt{2}*fs/4$ in the diagonal direction. For Green, the diagonal resolution has a maximum of $fsG/2=fs/\sqrt{2}$ and $fs/2$ in the horizontal and vertical directions. Because of their symmetry, the Nyquist domains of the Red, Blue and Green colors can be drawn in a single diagram, showing only a quarter. R/B indicates the Red/Blue domain and G indicates the Green domain. The desired domain is indicated by the 1/4 circle, while the full square corresponds to the domain of a 3 CCD camera.

It is possible to compare the Nyquist domain of a single RGB Bayer sensor with the square domain of a 3 CCD camera in which each sensor has the same sampling frequency 'fs' as the Bayer sensor. Since the human eye has a rotationally symmetrical resolution, a more realistic domain for comparison purposes is the circular shape. This desired domain can be regarded as being representative of a full VGA or XGA, or any other format, for each RGB color.

As has been illustrated in Fig. 3B, it appears that the color Green near the Nyquist frequency fs/2 does not truly fulfil the idea of the Nyquist theorem, i.e. there are clearly visible distortions. The same can be seen for the Red and Blue sampled colors, but then in the diagonal direction. The most annoying aspect is that no distinction of a direction is possible: the original scene may consist of horizontal and vertical lines. Considering the amount of aliasing of a sampled zoneplate, a better approximation of a new domain is shown in Fig. 3B. At the new border, only a small amount of aliasing can be noticed. Near the old border, the amount of aliasing increases.

The conclusion is that the Red and Blue signals, but especially the Green signal offer less resolution than is suggested by the Nyquist theorem. The amount of Green

A very attractive smart Green method especially for digital signal processing is offered by sorting the data of G12, G34 and RBc in order of magnitude. The center value of the sorted sequence, or in other words, the median value will be applied for the reconstruction of the missing Green pixel. Thus, smartG = median { G12, G34, RBc }

The RBc values for a Red and Blue center pixel are:

RBc = SmartGainR * SmartGawbR * Red value

RBc = SmartGainB * SmartGawbB * Blue value.

Note that the product of SmartGainX and SmartGawbX can be sent as one parameter by means of a controller to the multiplier which calculates RBc. The need for applying SmartGainX and SmartGawbX is explained below. Moreover, it will become clear why the smart Green processing can only reconstruct the missing Green pixel for near-white colors.

A more complex method, with the same results as the sorting algorithm, is offered by the fading algorithm. The default fade value is set at 0.5, resulting in a missing pixel reconstruction which is equal to the average Green value sigmaG when there is no smartG fade action. For RBc, the very same holds as what has been set out above, and the direction for resolution improvement is determined with the aid of this RBc value.

First, the situation is judged for G12 > G34, then

if G12-sigmaG > minG, then

fade = 0.5*(1 +(RBc-sigmaG)/(G12-sigmaG));

if fade > 1 then fade = 1 else if fade < 0 then fade = 0

SmartG = fade*G12 + (1-fade)*G34

else smartG = sigmaG

For the calculation of fade and smartG, it holds that:

if RBc > sigmaG then white dominance (=vertical resolution improvement), and if RBc < sigmaG then black dominance (=horizontal resolution improvement), but if RBc = sigmaG then smartG = sigmaG.

It will not be difficult to imagine that this direction detection algorithm will function satisfactorily for near-white signals, where R, G and B have approximately the same values. For more saturated colors, the reconstruction will start to fail, but from a perceptive point of view, near-white, high-frequency parts will be much better observed than highly saturated high-frequency parts. This is what makes the smart Green algorithm very attractive for application with the illustrated configuration of a missing Green pixel.

The use of a fader guarantees that, as a function of G12, G34 and RBc, a

A simpler fader algorithm was also examined with the aid of simulation software. In comparison with the previously discussed algorithm, it causes more distortions in the reconstructed smartG signal, is less accurate for smaller signal amplitudes and has a smaller near-white area. For this simpler fader algorithm, it holds that fade = 0.5*RBc/sigmaG.

The near-white area of smartG is understood to be the area in the color domain where the Green reconstruction acts satisfactorily. Fig. 5A shows the RGB color gamut with the near-white area. Although it is a sliding algorithm, smartG outside this area will be rather quickly equal to sigmaG, the average Green value. In order to achieve a more symmetrical area, the SmartGainR and SmartGainB parameters are increased from 1.0 to 2.0, resulting in the near-white area in Fig. 5B.

To judge the effective smartG near-white area, a 2D zoneplate is applied. By varying the RGB amplitudes, an estimation can be given as to what level smartG acts satisfactorily. For pure white, the amplitude range is very large for a good smartG performance and can be varied from at least 10% to 100%. The problem is, however, the spread in amplitudes, resulting in a limited and asymmetrical area in the RGB color domain. The area can be adjusted to a more symmetrical one by means of SmartGainR/B.

For a satisfactorily functioning smartG processor, i.e. acting near white, it is preferred that the Red and Blue values in the RBc variable are corrected with the respective white balance gain factors awbR and awbB, i.e. SmartGawbR = awbR and SmartGawbB = awbB. Depending on the location of the white balance correction, two block diagrams are possible for implementing the smartG processing.

In Fig. 6A, the white balance correction WBC is performed before the reconstruction of the RGB colors. The reconstruction of the RGB colors is carried out in a processor PROC which interpolates the RGB output signals Rout, Gout, Bout in known manner with regard to the red and blue color samples, and, in accordance with the present invention, with regard to the green samples. Note that the method of Fig. 6A can be used for RGB color filter arrays only, and cannot be used for complementary arrays like YeGCy arrays. In that case, the white balance correction can be effected in the analog signal path of the correlated double sampling (CDS) and A/D conversion (ADC) circuit (offering a better quantization performance of the digital signal), or in the digital path after the ADC. For this white balance method, the SmartGawbR/B parameters are equal to 1.0 and do not need to be controlled.

Fig. 6B shows a white balance correction WBC after the RGB and smartG

SmartGawbR = EGiwb/ERiwb, SmartGawbB = EGiwb/EBiwb

in which EGiwb, ERiwb and EBiwb are derived by means of the following matrix multiplication:

$$\begin{matrix} ERiwb \\ EGiwb \\ EBiwb \end{matrix} = \begin{matrix} 1 \\ 1 \\ 1 \end{matrix} \times \begin{matrix} b11 & b12 & b13 \\ b21 & b22 & b23 \\ b31 & b32 & b33 \end{matrix}$$

in which the matrix coefficients b11 thru b33 form the inverse matrix coefficients of the RGB matrix coefficients a11 thru a33 used in the camera signal processing. However, if false colors occur (to be discussed below), the camera matrix coefficients need to be adapted as follows:

a11 = a11

a12 = a12*awbR

a13 = a13*awbR

a2x = a2x (no adaptations to the green matrix coefficients)

a31 = a31*awbB

a32 = a32*awbB

a33 = a33

1.4 with white balance and matrix after the RGB processor PROC:

SmartGawbR = EGiwb/ERiwb, SmartGawbB = EGiwb/EBiwb,

in which EGiwb, ERiwb and EBiwb are derived by means of the following matrix multiplication:

$$\begin{matrix} ERiwb \\ EGiwb \\ EBiwb \end{matrix} = \begin{matrix} 1/awbR \\ 1 \\ 1/awbB \end{matrix} \times \begin{matrix} b11 & b12 & b13 \\ b21 & b22 & b23 \\ b31 & b32 & b33 \end{matrix}$$

2. <u>YeGCy Bayer sensor</u>

2.2 with white balance after the RGB processor PROC (as discussed above):

SmartGawbR=1 / (1 + 1/awbR), SmartGawbB=1 / (1 + 1/awbB)

2.4 with white balance and matrix after the RGB processor PROC:

SmartGawbR = EGiwb/ERiwb, SmartGawbB=EGiwb/EBiwb,

in which:

$$\begin{matrix} ERiwb \\ EGiwb \end{matrix} = \begin{matrix} 1/awbR \\ 1 \end{matrix} \times \begin{matrix} b11 & b12 & b13 \\ b21 & b22 & b23 \end{matrix}$$

as "falsecolor" is set to be true. If this condition is not fulfilled, this boolean is set to be false. The falsecolor boolean, if true, is used for the false color elimination action itself and also for the calculation of the fader value when the false color elimination is executed with a fader. If the falsecolor detection boolean is set to be true, then two methods at two locations are possible for eliminating the false colors. The first method relates to a hard switching color killer, the second is a fading version.

The first location is the same as where the smartG processing takes place, the other one is located where the luminance signal Y and the (low-pass filtered) color difference signals R-Y and B-Y are available. The following overview shows the False Color elimination possibilities FC1 thru FC4, each of which will be elucidated below.

FC1:	eliminate by switching at location SmartG
FC2:	eliminate by fading at location SmartG
FC3:	eliminate by switching at location Y, R-Y, B-Y
FC4:	eliminate by fading at location Y, R-Y, B-Y

FC1: False color elimination by switching at the smartG location.

With the white balance control before the smart Green processing and the falsecolor boolean set true, it holds for the elimination action that Red = Gc and Blue = Gc. In accordance with simulations, the FClevel should be adjusted to 1/16 of the full signal range (100 IRE) with 100% modulation depth at fs/2 (i.e. at 8 bits and 256 gray levels, the FClevel is 16).

If the signal-to-noise ratio is about 26 dB, the FClevel should be increased to 1/8 of the full range in order to prevent undesired color killing. The signal-to-noise ratio is unweighed over a bandwidth of fs/2 and is measured on the Green signal.

If the white balance is located after the smart Green processing, the Red and Blue false color results have to be divided by awbR and awbB, respectively, the white balance Red and Blue gain controls, in order to prevent Red and Blue from being twice corrected to white in the case of false color killing. In that case and with the false color boolean set true, it then holds for the false color elimination that:

Red = Gc/SmartGawbR and

Blue = Gc/SmartGawbB.

Fig. 8 shows a first embodiment of a color sample interpolator with false color killer. The RGB input signal RGBin from the sensor is applied to a processor PROC'

needed: Red = Gc/SmartGawbR and

Blue = Gc/SmartGawbB.

For all of the four elimination possibilities FC1 thru FC4 it holds that the false color detection is performed at the smartG location under the same condition:

'if abs(Gc-sigmaG) > FCgain*FClevel, then etcetera'.

The same adjustments for FCgain and FClevel hold as mentioned before, as well as the same transfer characteristic for Red and Blue as a function of Gc.

With the falsecolor boolean being true, the following action takes place at the R-Y/B-Y location:

R-Y = O and B-Y = O, (or U = O and V = O)

FC4: False color elimination by fading at the R-Y/B-Y location.

If the falsecolor boolean is true, the following fading action takes place:

FCfade = abs(Gc-sigmaG) / FCfadelevel

U' = (1-FCfade) * U

V' = (1-FCfade) * V

For FCfade = 1 the color difference signals become zero.

Inclusive of the dashed FCfade line, Fig. 9A shows the block diagram of this FC4 method. The RGB input signal RGBin from the sensor is applied to a processor PROC' which carries out the RGB reconstruction using the smartGreen algorithm to obtain green, and detects the presence of false colors (output boolean falsecolor). The red signal R and the blue signal B from the processor PROC' are applied to the white balance control circuit WBC to obtain a red signal R" and a blue signal B". A matrix circuit MX converts the green signal smartG from the processor PROC', and the red signal R" and the blue signal B", into a luminance signal Y and chrominance signals V and U. The matrix MX preferably also carries out a gamma correction operation. A false color killer circuit FCK' corrects the chrominance signals V and U in dependence upon the boolean falsecolor to obtain corrected chrominance signals V' and U' which are low-pass filtered by a low-pass filter LPF to obtain output chrominance signals Vout and Uout. The luminance signal Y from the matrix circuit MX is subjected to a corresponding delay in a delay circuit DL which supplies the output luminance signal Yout. As discussed above, a color matrix B (with coefficients b11 thru b33 as set out above) is preferably inserted between the RGB and smartGreen processor and false color detector PROC', and the white balance control circuit WBC. A red output signal r and a blue output signal b of the color matrix B are supplied to the white balance control circuit

of which is added to the luminance signal obtained by the RGB-to-YUV matrix to obtain an output luminance signal. In the embodiment of Fig. 9A, the matrix circuit MX comprises a conventional RGB-to-YUV matrix circuit which converts the output signal g of the color matrix B and the output signals R" and B" of the white balance control circuit WBC into a luminance signal and the chrominance signals V and U. The smartGreen signal smartG is high-pass filtered by a high-frequency white-processing unit I, LPF2, DL2, A1 of the type shown in Fig. 9B, the output signal Yw of which is added to the luminance signal obtained by the RGB-to-YUV matrix to obtain the luminance signal supplied by the matrix MX.

An evaluation of the false color elimination in accordance with the invention results in the following considerations. As regards the minimum FClevel of the false color detector, the false color elimination requires a relatively large level in order to avoid undesired and clearly visible color killing actions which look like defect pixels. In simulations at 100% modulation depth at fs/2, a minimum FClevel of 1/16 of 100 IRE for the absence of Gc and of 1/8 for the presence of Gc is required. Here, it also holds that at a lower total modulation depth at fs/2, the FClevels can be decreased proportionally.

As regards a switching or fading false color killer, the fading version is slightly in favor when the perception results of the switching and fading false color elimination are compared. The differences can be noticed only in a very few pictures.

As regards the best performing false color killer location, the R-Y/B-Y location is slightly in favor when the locations of the false color killer are compared, because in the case of an undesired color killing action the LPF will smear it out to a less visible artifact. Another advantage of the R-Y/B-Y location is that no divider circuits are needed (Red = Gc/SmartGawbR and Blue = Gc/SmartGawbB).

As regards the influence of SmartGainR/B on the false color killer, simulations have proved that these parameters, if larger than one, start improving the performance of the false color killer as far as less undesired color killing actions are concerned.

As regards only false color elimination in the presence of center Green, it is not possible to eliminate false colors at the missing Green pixel. However, without smart Green, the false color elimination in the presence of Green only offers a reduction of the total amount of aliasing of 50%.

Fig. 10 shows a simplified diagram of a camera comprising a sensor S with an RGB Bayer filter in accordance with Fig. 1A, and a parallel 2D Laplacian contour and RGB processing for an RGB Bayer sensor inclusive of smart Green. The contour signal

holds that only the Green data pixels are sampled, stored and shifted. For all inputs to the smart Green processor smartGproc, so also the RBc signal, it holds that they are first processed with a zero switch box, resulting in the following full clock speed RBc and Green pixel data.

For RBc:
RORORO
OBOBOB etc.,
For Green:
OGOGOG
GOGOGO etc.

Note that such a zero switch box, for Red and Blue data only, is also used at the input of the R/B processor R/Bproc, resulting in the reconstructed Red and Blue output signals Ro, Bo.

The smart Green signal smartG from the smart Green processor smartGproc is applied to the two row delay contour processor CONTPROC. A total number of 4.5 row delays is needed in the embodiment of Fig. 12.

In the embodiment of Fig. 12, one single smart Green processor smartGproc has been used. Fig. 13 shows an embodiment with three parallel smart Green processing blocks, in which only 3.5 row delays are needed for contour processing with the smart Green signal. The smart Green processors smartGproc and also the R/B processor R/Bproc have a zero switch box at the input. The zero switch box for the upper and lower smart Green block have the same timing. The 3 row-delayed RBc signals are obtained from the RBc row delays R/Bdel before the RBc processing. Note that if the smart Green processing is executed with the sorting algorithm, each smart Green block needs its own multiplier for the product RBc*SmartawbX (X stands for a Red or Blue RBc signal). The parameters SmartawbR and SmartawbB also include the SmartGainX parameter. SmartawbR or SmartawbB is selected in each smart green block and depends on the presence of a Red or Blue RBc signal.

An improved false color detector can be added to the 2D Laplacian contour processing block CONTPROC in Figs. 11-13. For detecting false colors, the smallest possible detection area can now be used. Two different detection areas are needed in the false color detector as described above, one for the location where Green is present (Fig. 7A) and one for the location where Green is absent (Fig. 7B), but where the reconstructed smart Green is available. Since, due to the extra row delays, the smart Green signal smartG

Smart green processing is a method of improving the resolution of the green signal in the horizontal and vertical directions. Apart from the color reproduction, the object of smart green processing is, to approximate very closely the quality of a three-sensor RGB camera, in other words, providing true VGA, XGA or whatever size with a single RGB Bayer sensor color camera.

The following features are preferably present. The smart Green (=missing pixel) reconstruction algorithm by means of the sorting, fading and simple fading algorithm for several sensor types like RG/GB- and YG/GC Bayer, RGG/GGB- and RGGG,GGBG-types, for two-sensor cameras with a Green and an RB/BR sensor (smart reconstruction of R and B). The correction of the near-white area with extra gain for the Red and Blue signal in the smart Green reconstruction algorithm. The correction of the missing pixel value with the white balance parameters.

A further aspect of the invention can be summarized as follows. Red-Green-Blue (RGB) or Yellow-Green-Cyan (YGC) Bayer color arrays suffer from colored aliasing (false colors) which is caused by the limited Nyquist area of the RB or YC pixels. half the contribution of the total aliasing can be eliminated by means of a false color detector using the center Green pixel and the other four diagonally surrounding Green pixels. No false color detection is possible at the missing Green location. However, when using the missing pixel reconstruction as described above, the second part of the colored aliasing can be eliminated with the same algorithm and using the horizontal and vertical surrounding pixels. The result is that the colored aliasing in a test scene like a zoneplate is completely killed. In normal scenes, not all but much aliasing is killed.

The following features are preferably present. The elimination of false colors at the location where Green is present and where Green is absent, inclusive of the adaptation of the false color levels for each. Note that the smart Green reconstruction algorithm is required first at the missing Green location. The switching and the fading color killer method. The adaptation of the false color killer level as a function of the overall Modulation Transfer Function of the lens, optical low-pass filter and light-sensitive window of the sensor. The adaptation of the result of the false color killer when it is executed before the white balance. The application of a diagonal optical low-pass filter for higher optical resolution in the case of smart Green with its false color killer.

Another aspect of the invention can be summarized as follows. An improved contour processing and an improved false color killer, both with the smart Green signal for RGB Bayer sensors, are based on the following considerations. The Nyquist

CLAIMS:

1. A method of interpolating a color sample in a signa! (RGBin) having alternately colored samples, the method comprising the steps of:

providing neighbouring color samples (G1, G2, G3, G4) of the same color (G) as the color sample to be interpolated;

providing a differently colored sample (R/B) from the same location as the color sample to be interpolated; and

interpolating the color sample to be interpolated in dependence upon the neighbouring color samples (G1, G2, G3, G4) of the same color (G) and the differently colored sample (R/B) from the same location, to furnish an interpolated color sample.

2. A method as claimed in claim 1, wherein said interpolating step comprises the steps of:

determining a horizontal average of horizontally neighbouring color samples (G1, G2) of the same color (G) as the color sample to be interpolated;

determining a vertical average of vertically neighbouring color samples (G3, G4) of the same color (G) as the color sample to be interpolated;

furnishing a median of said horizontal average, said vertical average, and said differently colored sample (R/B) from the same location.

3. A method as claimed in claim 1, wherein said interpolating step comprises the steps of:

determining a horizontal average of horizontally neighbouring color samples (G1, G2) of the same color (G) as the color sample to be interpolated;

determining a vertical average of vertically neighbouring color samples (G3, G4) of the same color (G) as the color sample to be interpolated;

calculating a weighed average of said horizontal average, said vertical average, in dependence upon said differently colored sample (R/B) from the same location.

4. A method as claimed in claim 1, wherein said interpolating step comprises the step of multiplying said differently colored sample (R/B) from the same location by a white balance adjustment factor before said differently colored sample (R/B) is taken into account.

15. A device for interpolating a color sample in a signal (RGBin) having alternately colored samples, the device comprising:

means for providing neighbouring color samples (G1, G2, G3, G4) of the same color (G) as the color sample to be interpolated;

means for providing a differently colored sample (R/B) from the same location as the color sample to be interpolated; and

means for interpolating the color sample to be interpolated in dependence upon the neighbouring color samples (G1, G2, G3, G4) of the same color (G) and the differently colored sample (R/B) from the same location.

16. A camera, comprising:

a sensor (S) having a color array having alternately colored color elements for providing a signal (RGBin) having alternately colored samples; and

an interpolating device (RGBproc) as claimed in claim 15.

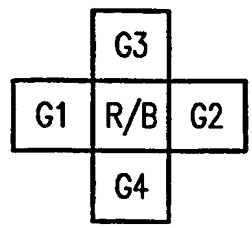


FIG. 4

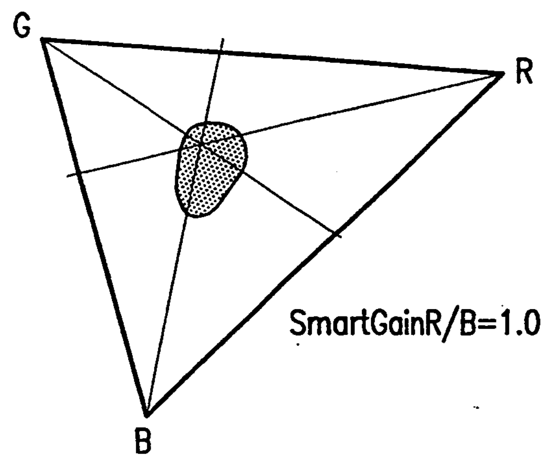


FIG. 5A

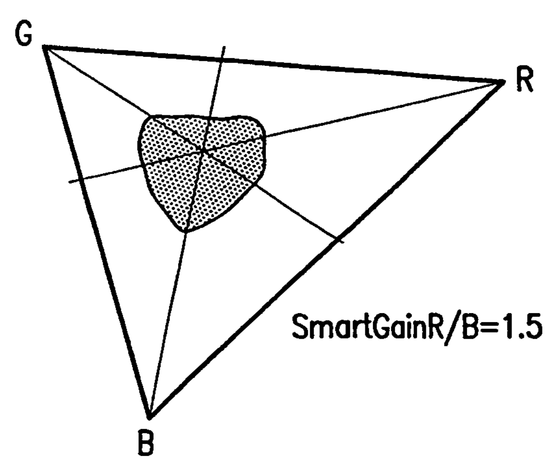
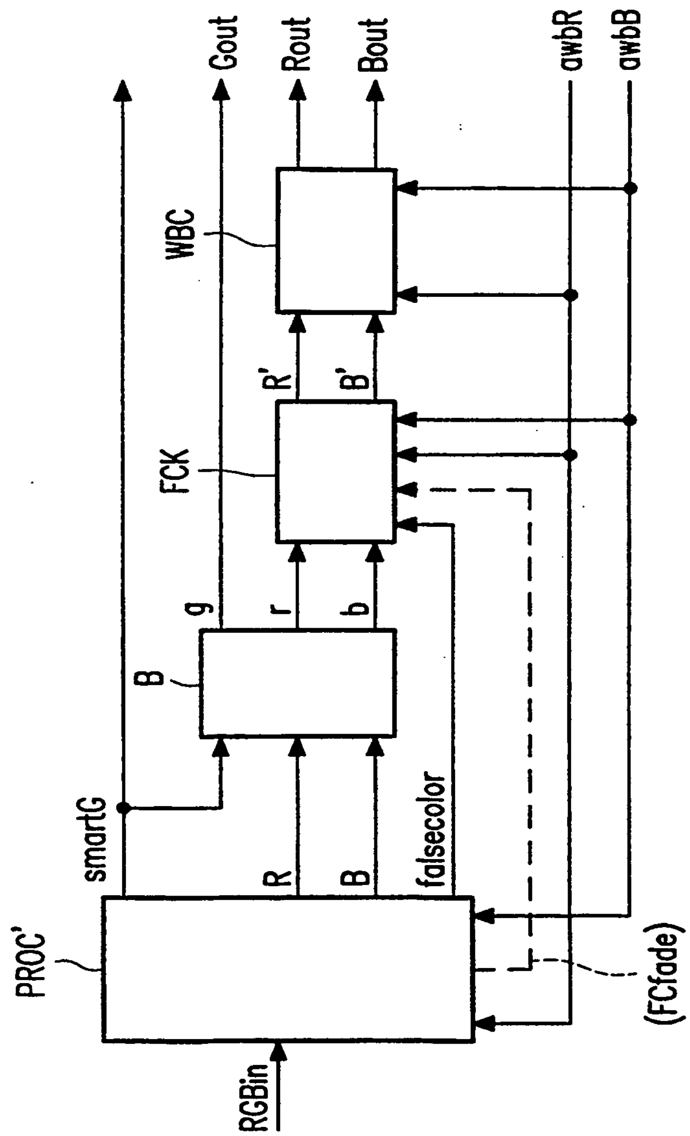


FIG. 5B


Gout
Rout
Bout
awbR
awbB
WBC
FCK
R'
B'
g
r
b
B
smartG
R
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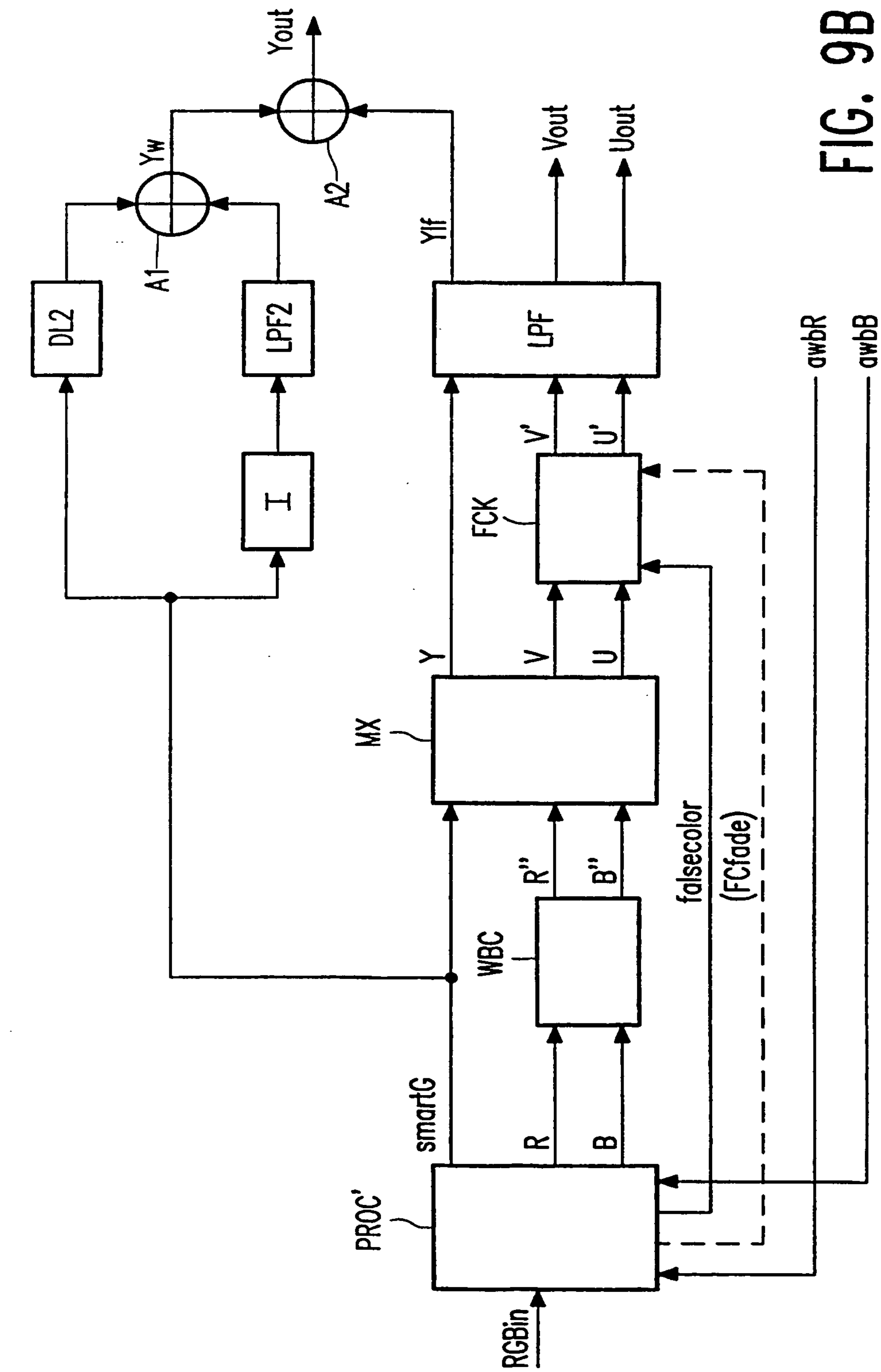
falsecolor
PROC'
(FCfade)
RGBin

FIG. 8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Yw
A1
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LPF2
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RGBin
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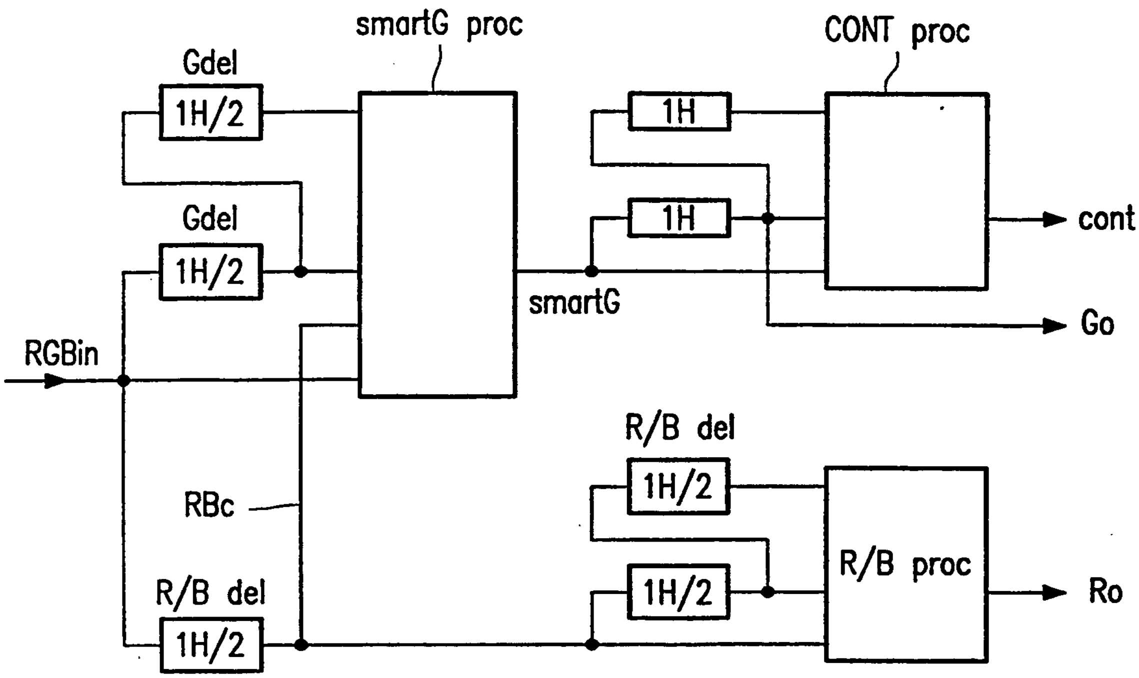
awbB

FIG. 9B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smartG
1H
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Go
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1H/2
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R/B proc
Ro

FIG. 12

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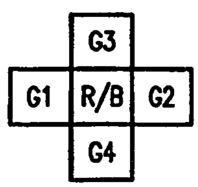

(57) Abstract

In a method of interpolating a color sample in a signal (RGBin) having alternately colored samples, the missing color sample is interpolated in dependence upon neighbouring color samples (G1, G2, G3, G4) of the same color (G) as the color sample to be interpolated, and a differently colored sample (R/B) from the same location as the color sample to be interpolated.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 98/00917

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04N 3/15, H04N 9/04
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5333055 A (HARUHIKO MURATA ET AL), 26 July 1994 (26.07.94), column 5, line 12 - line 44; column 7, line 63 - column 8, line 2; column 9, line 6 - column 12, line 12, abstract	1-4,6-11, 14-16
A		5,12-13
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Y	US 5119180 A (SATORU OKAMOTO), 2 June 1992 (02.06.92), column 5, line 12 - column 9, line 30, abstract	1-4,6-11, 14-16
A		5,12-13
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A	US 5629734 A (JOHN F. HAMILTON, JR. ET AL), 13 May 1997 (13.05.97), abstract	4-16
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 January 1999	18 -01- 1999
Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

01/12/98

International application No.
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